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Nutrient Management Technical Guide

for Golf Courses in the Rappahannock Watershed

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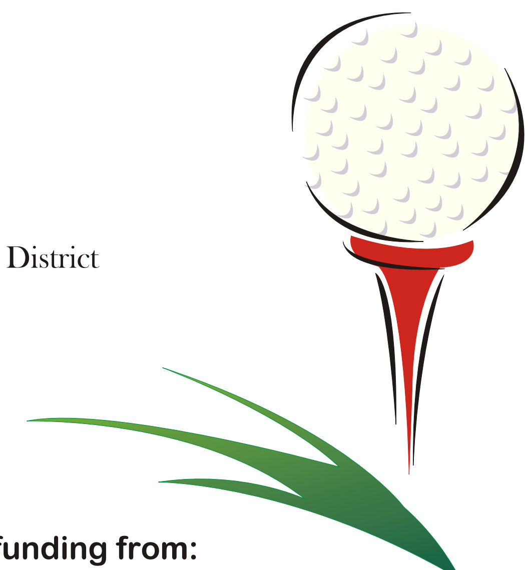

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I. Introduction:

Golf Courses are some of the most aesthetically pleasing and leisurely satisfying places on earth. Turfgrasses found on golf courses help to clean the environment by intercepting pesticides, fertilizers, dust and soil. Grasses also release oxygen, reduce glare, noise and summer temperatures. It is only fair that golf courses be managed in a way that maximizes the efficiency of turfgrasses to ensure continued enhancement of the environment.

The idea behind nutrient management is to maximize growth and health of a plant species while minimizing the use of costly and possibly environmentally damaging products. By applying this idea to the Rappahannock Watershed and the golf courses within, the goal is to maximize turfgrass quality while minimizing the loss of nutrients to the environment and in turn reducing the potential for ground water leaching and runoff to the Rappahannock River.

Goals:

In development of this guide, the preliminary goals were to:

- ■ Identify and record all of the existing and planned golf courses in the Rappahannock Watershed.
- ■ Collect all of the available information pertaining to
- • commonly planted course grasses and their desired performance
- • plant nutrient recommendations for course maintenance and establishment
- • soils, as related to nutrient management
- • proper timing, rate, and application of nutrients
- • a list of soil types, highly leachable and highly erodible soils
- • a list of environmentally sensitive areas
- • climatic data
- • a list and description of accepted best management practices (BMP's).
- ■ Produce a draft Nutrient Management Technical Guide for use by golf courses located within the Rappahannock Watershed that will later be reviewed by a technical staff with expertise in the above mentioned areas and then distributed in its final form.
- ■ Strengthen partnerships with cooperating agencies, local governments, universities, and golf courses in our community.
- ■ Protect and/or improve water quality of the Rappahannock River through sound nutrient management on area golf courses.
- ■ Provide golf course management with written nutrient management guidelines.

Now that the preliminary goals have been reached there are two main goals that, if achieved, will make the work put into the development of the guide all worth while. Those two goals are to:

- ■ Reduce the potential for nutrients flowing into the Rappahannock River and ultimately the Chesapeake Bay.
- ■ Reduce operational costs on golf courses through the efficient use of fertilizers and the practice of best management techniques.

Uses:

This guide has been developed for the benefit of the Golf Course Superintendent and maintenance crew. The information within is a tool for golf course management. By extracting specific information pertaining to a specific course in the watershed and applying the associated nutrient recommendations and various BMP's, conditions on the course can be enhanced and the maintenance costs can be reduced.

Though they are not listed as such, Best Management Practices (BMP's) are described throughout this manual. Any suggestion made toward increased health of turfgrass, decreased potential for leaching and runoff, etc., are techniques that should be implemented to best manage a golf course and protect water quality.

The Big Picture:

Why is nutrient management so important? Why worry about nutrients reaching the Rappahannock River or any surface water supply? The reason is pollution, Nonpoint Source to be exact. NPS pollution is the biggest threat to water quality in the Chesapeake Bay. While nutrients are essential to healthy vegetation on land, they contribute greatly to NPS pollution in our waterways.

Excess nutrients in lakes, rivers and Bays have numerous damaging effects. These include, but are not limited to, algae blooms, reduced dissolved oxygen levels, loss of sub-aquatic vegetation and bottom dwelling organisms, and contamination of our drinking water supplies. The Rappahannock River is one of the most polluted tributaries to the Chesapeake Bay. It is up to everyone in the Rappahannock Watershed to help reduce the amount of NPS pollution reaching the river.

List of Established and Operating Golf Courses in the Rappahannock Watershed: (as of May 2000)

County	Course Name
Caroline	Four Winds Golf Course
Culpeper	Country Club of Culpeper
	South Wales Golf Club
Essex	Hobbs Hole Golf Course
	Woodside Country Club
Fauquier	Fauquier Springs Country Club
	Kastle Greens
Fredericksburg	none
Greene	Greene Hills
King George	Cameron Hills
Lancaster	The Tides/Golden Eagle Golf Course
	The Tides/The Tartan Course
	Windjammer Golf Course
Madison	Woodberry Forest Golf Course
Middlesex	none
Orange	Browning Golf Course
	Lake of the Woods Golf Course
	Meadow's Farm Golf Course
	Somerset Golf Course
Rappahannock	none
Richmond	none
Spotsylvania	Fawn Lake Country Club
	Fredericksburg Country Club
	Lee's Hill Golfers' Club
Stafford	none
Westmoreland	none

III. Map of Watershed: Figure 1

County Boundaries

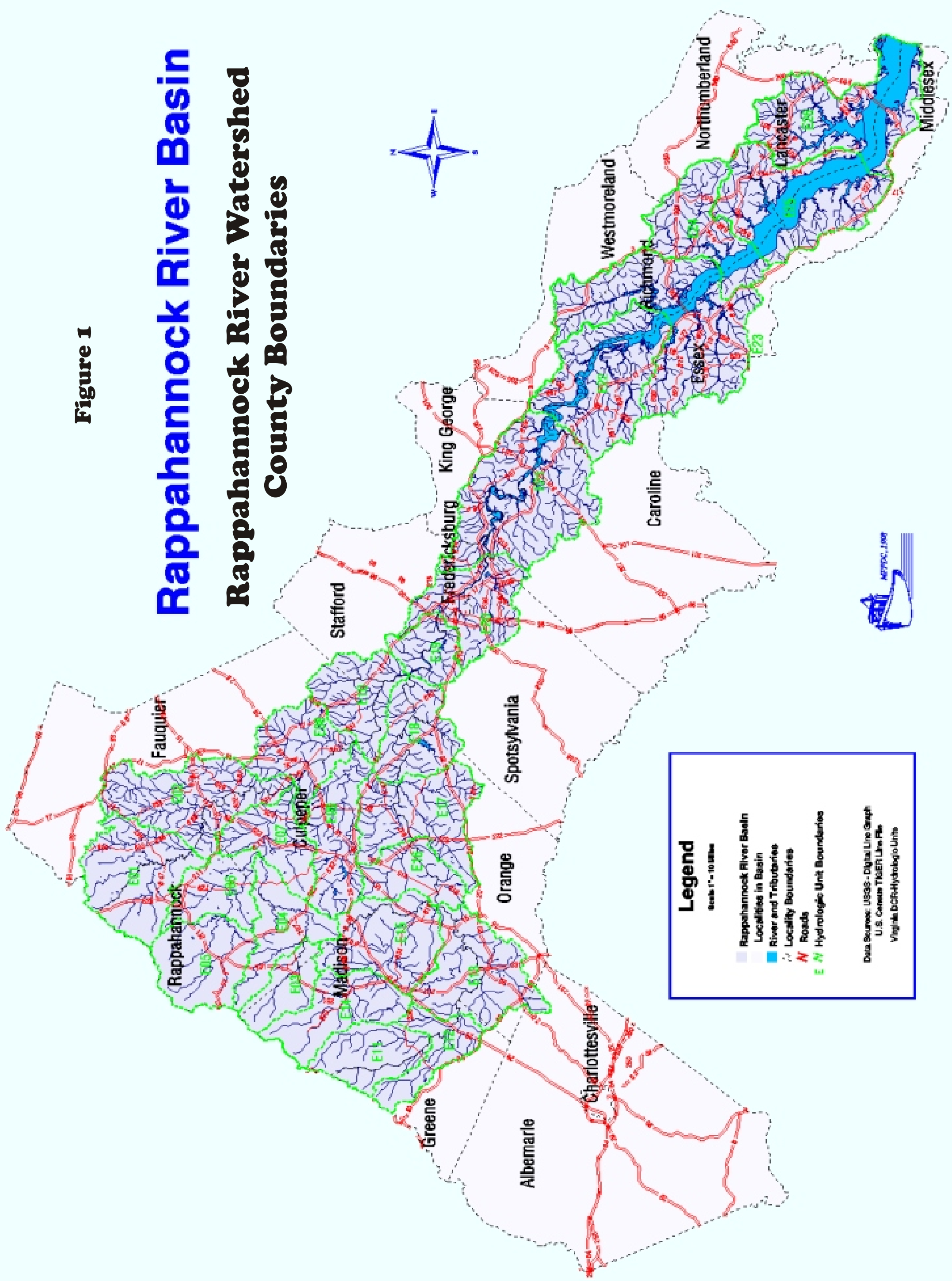
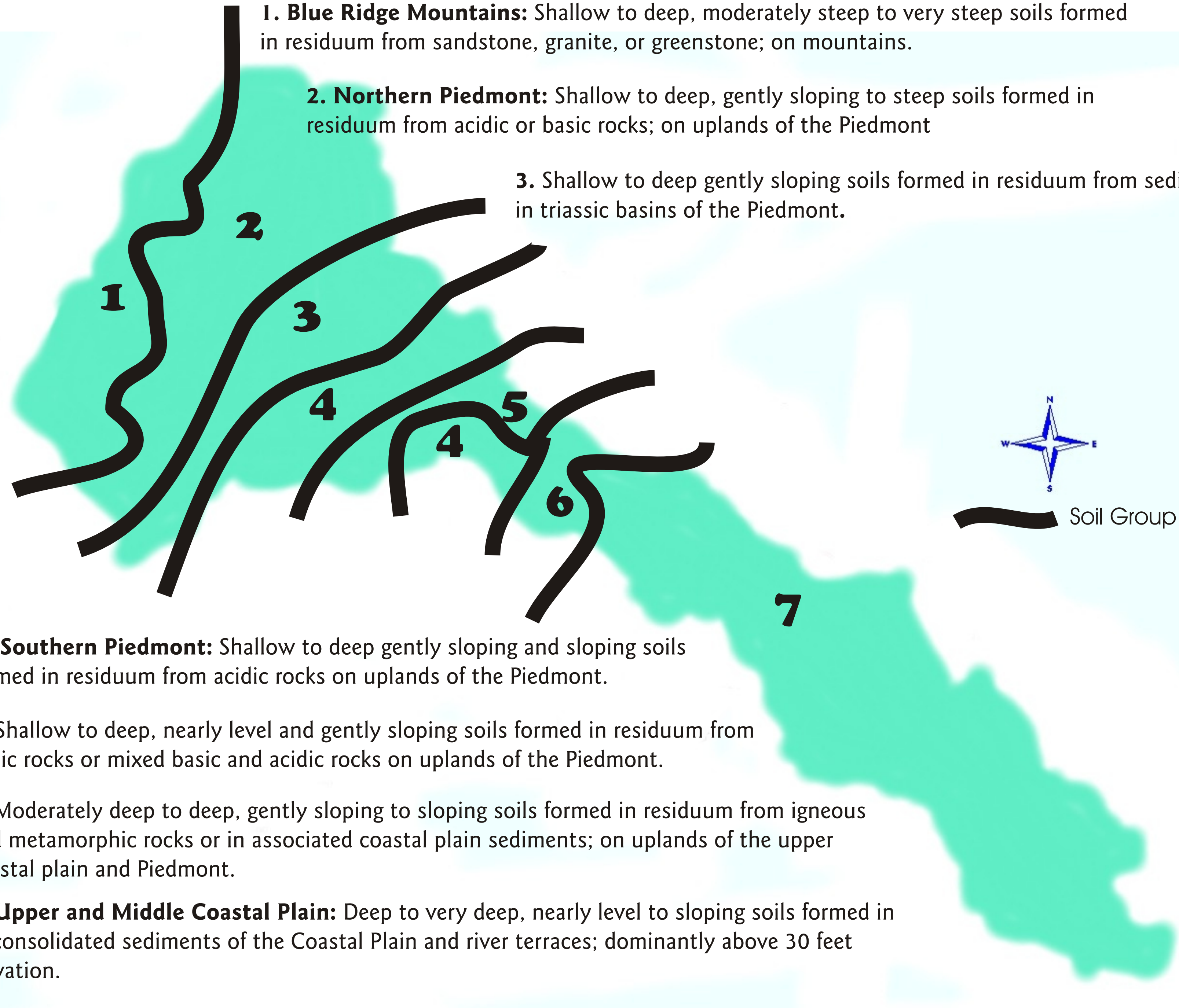


Figure 2

Rappahannock River Watershed General Woil Map



1. Blue Ridge Mountains: Shallow to deep, moderately steep to very steep soils formed in residuum from sandstone, granite, or greenstone; on mountains.

2. Northern Piedmont: Shallow to deep, gently sloping to steep soils formed in residuum from acidic or basic rocks; on uplands of the Piedmont

3. Shallow to deep gently sloping soils formed in residuum from sedimentary rocks in triassic basins of the Piedmont.

4.. Southern Piedmont: Shallow to deep gently sloping and sloping soils formed in residuum from acidic rocks on uplands of the Piedmont.

5. Shallow to deep, nearly level and gently sloping soils formed in residuum from basic rocks or mixed basic and acidic rocks on uplands of the Piedmont.

6. Moderately deep to deep, gently sloping to sloping soils formed in residuum from igneous and metamorphic rocks or in associated coastal plain sediments; on uplands of the upper coastal plain and Piedmont.

7. Upper and Middle Coastal Plain: Deep to very deep, nearly level to sloping soils formed in unconsolidated sediments of the Coastal Plain and river terraces; dominantly above 30 feet elevation.

IV. Soils Information:

Soil types vary in Virginia. Certain soil types have a greater potential to hold nutrients than do others. The ability to retain positively charged particles and nutrients is represented by the *Cation Exchange Capacity* (CEC) of the soil. The CEC is determined by the amount of clay and organic matter in the soil, both of which are negatively charged and will attract positively charged ions such as ammonium and potassium. Sandy soils, with lower clay content, have less ability to hold negatively charged ions like nitrates. These negative ions, if not held by the soil, have the potential to leach into groundwater if not used by the plant and exposed to significant rainfall.

Most greens are constructed of specified mixtures of sand, peat and clay. Having clay in a greens mixture reduces the potential for nitrogen and potassium leaching.

The following chart is a compilation of soils underlying the courses in the Rappahannock Watershed. Soil names and symbols were obtained from the Soil Survey Maps for each County. Leaching Indices were obtained either from the Soil Surveys or with help from Soil and Water Conservation District staff.

- Note that most soils have a leaching index of moderate to high.
- See Section V. for Special Reccomendations for Specific Leaching Indicies.
- ** indicates that a leaching index is not assigned to the soil type listed.

**VCE pubs. 430-398, 430-399

Specific Soil List with Leaching Indicies (by County and Goft Course):

County	Course	Soil Sym	Soil Name	Leaching Index
Caroline	**Four Winds**	1A	Altavista sandy loam, very rarely flooded	moderate
		3B	Bama sandy loam	high
		5B	Bojac sandy loam, very rarely flooded	high
		7A	Chastain loam, pounded	moderate
		8A	Chewacla silt loam	unknown
		11A	Kempsville-Emporia complex	high
		10E	Kempsville - Emporia-Remlix complex	high
		13E	Nevarc sandy loam	moderate
		15A	Rappahannock muck	moderate
		22B	Stagle fine sandy loam	high
		21C	Slagle-Kempsville complex	moderate
		23A	State fine sandy loam	high
		26A	Tomotely-Roanoke complex	high
		29A	Wickham fine sandy loam	high
Culpeper	**Culpeper CC**	Ac	Albemarle fine sandy loam, rolling phase	high
		Ad	Albemarle fine sandy loam, undulating phase	high
		Ct	Culpeper loam, eroded hilly phase	moderate
		Cv	Culpeper loam, eroded undulating phase	moderate
		Cw	Culpeper loam, rolling phase	moderate
		Db	Davidson clay, rolling phase	high
		Mk	Mixed alluvium	**
		Rb	Rapidan silty clay loam, eroded hilly phase	high
		Ra	Rapidan silty clay loam, eroded rolling phase	high
		Rc	Rapidan silty clay loam, undulating phase	high
		Sc	Starr silt loam	moderate
		Va	Very stony land, acidic rocks	moderate
		We	Wehadkee silt loam	moderate
Culpeper	**South Wales**	Ae	Aldino silt loam, eroded rolling phase	moderate
		Af	Aldino silt loam, undualting phase	moderate
		Cc	Catoctin silt loam	moderate
		Cm	Congaree silt loam	high
		Cr	Culpeper clay loam, eroded rolling phase	moderate
		Cw	Culpeper loam, rolling phase	moderate
		Ec	Elioake loam, eroded rolling phase	moderate
		Hg	Hazel loam, hilly phase	moderate
		Hh	Hazel loam, steep phase	moderate
		Ho	Hiwassee loam, undulating light-colored phase	high
		Lf	Lloyd loam, eroded rolling phase	moderate
		Ma	Manor silt loam, eroded hilly phase	high
		Sa	Seneca silt loam	high
		Sc	Starr silt loam	moderate
		Se	tony land, acidic soils	moderate
		Va	Very stony land, acidic rocks	moderate
Essex	**Hobbs Hole**	13A	Munden fine sandy loam	high

Key: ** leaching index not assigned to the soil type

Specific Soil List with Leaching Indicies (by County and Goft Course):

County	Course	Soil Sym	Soil Name	Leaching Index
Essex	**Woodside**	6B	Catpoint loamy sand	very high
		7A	Chickahominy silt loam	moderate
		9C	Emporia sandy loam	moderate
		10B	Kempsville sandy loam	high
		14A	Newflat silt loam	moderate
		17A	Rappahannock muck, frequently flooded	moderate
		19E	Rumford and Emporia soils	high
		20D	Rumford and Slagle soils	high
		23B	Suffolk sandy loam	high
		24A	Tetotum loam	moderate
		25A	Tomotely fine sandy loam	high
Fauquier	**Fauquier Springs**	55D3	Brinklow silt loam	moderate
		2A	Codorus loam, frequently flooded	moderate
		55C3	Elioak loam	moderate
		55C	Elioak loam	moderate
		53D	Glenelg loam	moderate
		95B	Goresville loam	moderate
		98C3	Goresville loam	moderate
		15B	Seneca loam	moderate
		3A	Suches loam, frequently flooded	moderate
Fauquier	**Kastle Greens**	79A	Albano silt loam	moderate
		74A	Ashburn silt loam	moderate
		78A	Dulles silt loam	moderate
		63A	Kelly variant silt loam	moderate
Green	**Green Hills**	MrB	Meadowville fine sandy loam	high
		CgB	Chatuge sandy loam	moderate
		Bud	Buckhall loam	high
		Enc3	Eliok clay loam	moderate
		End3	Eliok clay loam	moderate
		Bab	Belvoir sandy loam	moderate
King George	**Cameron Hills**	Ae	Albano silt loam	**
		AtB	Atlee silt loam	moderate
		GsD	Galestown-Sassafras complex	very high
		KfB	Kempsville fine sandy loam, gravelly substratum	high
		KfC2	Kempsville fine sandy loam, gravelly substratum, eroded	high
Lancaster	**Tartan Course**	Dr	Dragston fine sandy loam	moderate
		KeB	Kempsville fine sandy loam, thick surface, nearly level	high
		Mt	Mattapex silt loam	moderate
		SfA	Sassafras loamy fine sand, thick surface, nearly level	high
		SfB	Sassafras loamy fine sand, thick survace, gently sloping	high
		SsD	Sloping sandy land	**
		StE	Steep sandy land	**
		Wo	Woodstown fine sandy loam	moderate

Key: ** leaching index not assigned to the soil type

Specific Soil List with Leaching Indicies (by County and Goft Course):

County	Course	Soil Sym	Soil Name	Leaching Index
Lancaster	**Golden Eagle**	BeB2	Beltsville very fine sandy loam, gently sloping, eroded	high
		Br	Bertie silt loam	high
		CsB2	Craven silt loam, gently sloping, eroded	moderate
		Dr	Dragston fine sandy loam	moderate
		KeA	Kempsville fine sandy loam, nearly level	high
		KeB	Kempsville fine sandy loam, gently sloping	high
		KeB2	Kempsville fine sandy loam, gently sloping, eroded	high
		KeC3	Kempsville fine sandy loam, sloping, severly eroded	high
		Mt	Mattapex silt loam	moderate
		Mx	Mixed alluvial land	**
		SaA	Sassafras fine sandy loam, nearly level	high
		SaB	Sassafras fine sandy loam, gently sloping	high
		SaC2	Sassafras fine sandy loam, gently sloping, eroded	high
		SfA	Sassafras loamy fine sand, thick surface, nearly level	high
		SfB	Sassafras loamy fine sand, thick surface, gently sloping	high
		SsD	Sloping sandy land	**
		StE	Steep sandy land	**
		Wo	Woodstown fine sandy loam	moderate
Lancaster	**Windjammer**	Co	Coastal beach	**
		Dr	Dragston fine sandy loam	moderate
		Fa	Fallingston fine sandy loam	high
		Ot	Othello silt loam	moderate
		Th	Tidal marsh, high	**
		To	Tidal marsh, low	**
		Wo	Woodstown fine sandy loam	moderate
Madison	**Woodberry Forest**	DaB2	Davidson clay loam	high
		DaC2	Davidson clay loam, 7-15% slope	high
		CCC	Catoctin silt loam	moderate
		MuB	Mayodan fine sandy loam	high
		RdB	Rapidan silt loam	high
Orange	**Browning's**	NsB2	Nason silt loam	moderate
		NsC2	Nason silt loam	moderate
		TsB2	Tatum silt loam	moderate
		LgB	Lignum silt loam	moderate
		MrC	Manteo silt loam	moderate
Orange	**LOW**	LgB	Lignum silt loam	moderate
		Mx	Mixed alluvial land	**
		NsB	Nason silt loam	moderate
		NsC2	Nason silt loam, several eroded	moderate
		SeB	Seneca fine sandy loam	high
		TsB	Tatum silt loam	moderate
		TsC2	Tatum silt loam, eroded	moderate
		TtC3	Tatum silty clay loam, severly eroded	moderate
		WoB	Warsham silt loam	moderate
		YoB	York silt loam	moderate

Key: ** leaching index not assigned to the soil type

Specific Soil List with Leaching Indicies (by County and Goft Course):

County	Course	Soil Sym	Soil Name	Leaching Index
Orange	**Meadow's Farm**	BrC	Bremo silt loam	moderate
		CsC3	Cecil clay loam, severely eroded	high
		Eb	Elbert silt loam	moderate
		FIB2	Fluvanna silt loam, eroded	moderate
		MrC	Manteo silt loam	moderate
		Mx	Mixed alluvial land	**
		NsC2	Nason silt loam	moderate
		NtC3	Nason, silty clay loam, severely eroded	moderate
		OgB2	Orange silt loam, concretionary variant, eroded	moderate
		TsB2	Tatum silt loam, eroded	high
		WoB	Worsham silt loam	moderate
Orange	**Somerset**	AlA	Altavista loam	moderate
		AuA	Augusta silt loam	moderate
		Bw	Buncombe loamy fine sand	very fine
		Cw	Chewacla silt loam	moderate
		EsB	Elsinboro loam	high
		HsB	Hiwassee loam	high
		HsC2	Hiwassee loam, eroded	high
		MrD	Manteo silt loam	moderate
		MsB	Masada loam	moderate
		MsB2	Masada loam, eroded	moderate
		Rk	Roanoke silt loam	moderate
		SeB	Seneca fine sandy loam	high
		TuB	Turbeville loam	moderate
		TuB2	Turbeville loam, eroded	moderate
Spotsylvania	**Fawn Lake**	7B	Aquults, loamy-Margo complex	high
		9B	Brockroad silt loam	moderate
		11B	Catharpin silt loam	high
		22C2	Fluvanna fine sandy loam	high
		32C2	Nason silt loam	high
		33B	Orange-I redell loams	very high
		42B	Toddstav silt loam	very high
Spotsylvania	**Fred CC**	2B	Altavista sandy loam	high
		6A	Aquults, gravelly substratum	moderate
		10A	Cartecay sandy loam	high
		16A	Dogue loam	high
		17C	Dystrochrepts-Udults complex, sloping	**
		17E	Dystrochrepts-Udults complex, steep	**
		23A	Fluvaquents-Udifluvents complex	**
		44A	Udorthents, gravelly	**
		48A	Wickham loam	moderate

Key: ** leaching index not assigned to the soil type

Specific Soil List with Leaching Indicies (by County and Goft Course):

County	Course	Soil Sym	Soil Name	Leaching Index
Spotsylvania	**Lee's Hill**	2B	Altavista sandy loam	high
		6A	Aquults, gravelly substratum	moderate
		17D	Dystrochrepts-Udults complex, moderately steep	**
		17C	Dystrochrepts-Udults complex, sloping	**
		17E	Dystrochrepts-Udults complex, steep	**
		23A	Fluvaquents-Udifluvents complex	**
		25B	Kempsville gravelly sandy loam	moderate
		44A	Udorthents, gravelly	**
		45B	Udorthents-Udifluvents complex, gently sloping	**
		48A	Wickham loam	moderate

Key: ** leaching index not assigned to the soil type

V. Leaching:

Leaching occurs when nutrients (specifically inorganic forms of quickly available nitrogen, particularly nitrite and nitrate) are dissolved and carried with water down through the soil profile. Apart from being an economic loss, these nutrients are potential pollutants to groundwater water resources once they are leached below the root zone.

Factors that contribute to nutrient loss by leaching and runoff include the following:

- heavy, one-time applications of nitrogen fertilizers on sandy textured soils.
- over applications of manures or sludge to land.
- improperly timed applications of nitrogen fertilizer.
- poorly designed or non-existent soil conservation measures (usually not a problem on turfed areas).
- periods of exceptionally heavy rain.

**source: Nutrient Management Handbook, DCR

Special Recommendations for Specific Leaching Indices:

The leaching index for a soil is the potential for a given soil to be subject to nitrate and soluble nutrient leaching below the root zone. The leaching index uses hydrologic group, annual precipitation, and rainfall distribution data. Leaching indices have been assigned to each soil listed in this manual. To determine a soil's leaching index:

- Find the soil's hydrologic group, A, B, C, or D (usually in table 16 - Soil and Water Features in modern soil surveys)
- Determine the leaching index for the soil hydrologic group in which the field is located (also found in the Soil Survey).
- Determine the leaching potential based on the following scale:

  Low - Leaching index less than 2, probably will not contribute to leaching below the root zone.

  Moderate - Leaching index between 2 and 10, may contribute to leaching below the root zone. Wise nutrient management should be practiced.

  High - Leaching index between 10 and 15, will likely contribute to leaching below the root zone. Nutrient management should be intense.

  Very High - Leaching index above 15, will contribute to significant leaching below the root zone. Nutrient management should be extremely intense or soluble nutrients should not be applied.

**Nutrient Management Handbook, DCR

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- Leaching potential increases in the fall for warm season grasses.
- To reduce potential for leaching, apply nutrients when the plant has the best opportunity to take up the nutrient, before the leaching potential increases and the nutrient can be lost to the environment.
- See Section XI. to see how irrigation effects leaching potential.

Virginia Leaching Indices for Nitrates and Soluble Nutrients (by county):

	Hydrologic Groups			
County	A	B	C	D
Caroline	17	13	6	6
Culpeper	17	13	6	6
Essex	17	13	6	6
Fauquier	17	9	6	6
Greene	17	13	9	6
King George	17	13	6	6
Lancaster	17	13	6	6
Madison	17	13	6	6
Middlesex	17	13	6	6
Orange	17	13	6	6
Rappahannock	13	6	6	3
Richmond	13	9	6	3
Spotsylvania	17	13	6	6
Stafford	17	9	6	3
Westmoreland	17	13	6	6

VI. Soil Testing:

1. Why Test Soil?

Soil tests can be used to determine fertilizer needs for specific soil types. Identifying the soil underlying your course will help determine the correct amount of non-Nitrogen fertilizers needed for your tees, greens and fairways. The test results address P_2O_5, K_2O, Calcium, Magnesium, and other fertilizer types. Timely application of the correct amount of these substances will reduce leaching into groundwater, runoff into nearby waterways and overall waste. By reducing the amount of fertilizers that don't benefit your course, you will reduce the costs associated with maintaining the goals set for your course. Instead of paying for unused fertilizer, find out what your soils can handle and pay for and apply only that amount.

Be aware that soil tests do not address Nitrogen needs. Nitrogen applications are usually addressed in Nutrient Management Programs or Best Management Programs relating to turf species, use, growth characteristics, and season.

▪note: All of the following information applies to Soil Testing at the Virginia Tech Soil Testing Laboratory.

2. How to take samples for Soil Testing:

- Equipment needed: sampling tube, spade, trowel or auger, and *clean* plastic pail. Do not use a metal container as it may affect the results of the test. Clean equipment between samples.
- Obtain soil sample carton and associated literature at your local Soil and Water Conservation District or Virginia Cooperative Extension office.
- Wait a minimum of 3-4 weeks after last fertilization before sampling.
- Samples should be made up of at least five (5) sub samples or cores from each acre represented by the sample. Sample just below the root zone; 4 inches on roughs and fairways, 2 inches on tees and greens.
- Mix sample thoroughly in the pail before the sample carton is filled with soil.
- Be careful that samples are truly representative of the area being tested. Samples should represent individual fairways, greens, tees, etc.
- A different soil sample should be taken from each different uniform area on the course (i.e. tees, fairways, greens, rough). Do not take sub samples from eroded spots, back furrows or small depressions. Large areas on the course that have been fertilized, limed, or otherwise treated differently should be sampled separately.

(cont.)

- A plant tissue sample may be submitted with the soil samples. A plant tissue analysis is a diagnostic tool that can be used to identify potential nutrient problems. Plant analyses measure the concentrations of different nutrients in the tissue and indicate adequacy or deficiency.
- Be sure to sample every area on the course for the most complete results.

4. Instructions for Filling Out Soil Sample Information Sheet: (For Virginia Tech Soil Testing Lab only.)

- Be sure to obtain a *Soil Sample Information Sheet for Commercial Crop*
- *Production*.
- Fill out one Information Sheet for each soil sample.
- (i.e. 4 samples = 4 sheets)
- Print appropriate information in box concerning name and address. Be sure to include both county and city names for coding purposes. Name and address should also be printed on soil sample box. Include appropriate information concerning an extra copy.
- Unit Code is associated with County. Obtain Unit Code from the Soil and Water Conservation District in your county (or leave blank).
- Give each soil sample a name or number up to five digits/letters long. This name/number should also be printed on the sample box.
- Crop code and name is listed on the back of the Information Sheet.
- Commercial Turf Production codes are as follows:
  - 80. Putting Greens, Bentgrass
  - 81. Putting Greens, Bermudagrass
  - 82. Tees, Bentgrass
  - 83. Tees, Bermudagrass
  - 84. Fairways - Ky Bluegrass, Fescue
  - 85. Fairways - Bermudagrass
- If your plant is not listed here or on the back of the information sheet, place "299" in the box and write the name of the plant alongside the box.
- List the last fertilizer application for N (Nitrogen), P_2O_5 (Phosphate), and K_2O (Potash) by pounds/acre in the appropriate boxes. List any other pertinent information in the "Past History of Sampled Area" box.
- Obtain Soil Type and Soil Name from the Soil List in this manual.

5. How to Read and Interpret Soil Test Results:

- The Soil Test Report assesses your crop's need for fertilizer and lime.
- The Report section entitled "History of Sampled Area" restates the information you provided on the soil sample information sheet submitted with the sample for testing.
- The section entitled "Lab Test Results" expresses the relative availability of nutrients, numerically and, if appropriate, as a rating. The ratings may be interpreted as follows:

  L=Low
  M=Medium
  H=High
  VH=Very High
  EH=Excessively High (soluble salt test only)
  DEF=Deficient
  SUFF=Sufficient
- Plants almost always respond to fertilizer for soils testing Low, sometimes for soils testing Medium, and do not usually respond for soils testing High to Very High. If no rating is provided, the adequacy of that nutrient in the soil for the plant you specified has not been determined.

■ note: Soils in low-maintenance areas (roughs) should be tested every 2-3 years. Soils in more highly maintained or troublesome areas should be tested more often (1-2 years).

**VCE Supplements to Soil Test Reports
Water Quality and GC Supers, 6

VII. Turfgrasses:

Golf Course Turfgrass is available in two main categories: cool season and warm season. Cool season grasses grow best without stress during spring and fall and provide winter coloring in most areas of Virginia. Warm season grasses go dormant after the first hard frost and stay brown through the winter months. Warm season grasses have lower water requirements and have a shorter growing season per year. Turfgrasses come in several varieties not all will perform equally with the different climates and soils found throughout Virginia.

Proper fertilization of turfgrass will result in desired quality of the grass. Turfgrass quality is a measure of density, color, uniformity (free of weeds and foreign species of grasses), smoothness, growth habit and texture. Committing to proper turfgrass species and variety selection will help achieve high levels of quality. Proper nutrient management, pest management, and irrigation also enhance turfgrass quality.

*VCE pub. 430-011

Variety Descriptions:

- Bentgrass
  Cool seasnon stoloniferous grass used for golf greens. High maintenance is required; some varieties can be seeded while others must be vegetatively planted.

- Bermudagrass
  A warm season grass, varies in texture depending on the variety; fine-textured is common on golf courses. Bermudagrass turf will go dormant with the first hard frost in the fall and green up in late April to mid-May. Best adapted in the Southern Piedmont and Eastern Virginia, it is not recommended for higher elevations. It can be established from seed, sod, plugs, or sprigs; however, some varieties cannot be seeded and must be established vegetatively. Will grow on all types of soil, but is better suited to sandy and droughty soils than other grasses. Prefers well-drained soils.

- Bluegrass Kentucky
  A cool season, medium-textured turfgrass, it is best suited to moderate to high levels of sunlight and management. Fine-textured, well-drained soils are best, but it will grow well on moderately drained to somewhat poorly drained, fine-textured soils. It is established from seed or sod. Mixtures of blends of three or four Kentucky bluegrass varieties are recommended in Virginia since they are more likely to provide good quality turf over a wide range of management situations.

Variety Descriptions, cont.

- Fescue - Tall
  A cool season, moderately coarse-textured turfgrass, it is tolerant of a wide range of climatic extremes. Tolerant to both dry and wet soils. Best suited to areas where low to moderate management levels are provided. Established from seed or sod. Long-lived, tufted, deep-rooted; noted for early spring and late fall growth; leaves are dark green, shiny , and barbed along the edges, making them feel rough. Excellent when seeded at high rates for turf.

- Perennial Ryegrass
  A cool season grass, performs better at higher elevations (>1000 ft.). The most common use for perennial ryegrass is in a mixture with Kentucky bluegrass where the perennial ryegrass component is less than 15% by weight. Also used as winter turf or overseeding bermudagrass. Annual (Italian) ryegrass provides rapid germination and fast growth but is suitable only where a temporary turf is desired since it lives for only one year.

- Zoysiagrass
  A warm season grass, closely resembles Bermudagrass. Turns brown with frost but greens up somewhat earlier than Bermuda in the spring, late April or mid-May. It is not recommended at higher elevations due to its short growing season. Forms a dense turf with leaves upright, which provides more cushion than bermuda. Low moisture requirements, best adapted to intermediate zone between cool-humid and warm-humid regions. Grows best in soils of medium to good fertility. Will survive at low fertility levels. Tolerates medium acidity, but needs good drainage. Moderately shade-tolerant.

Favorable Growing Conditions for Turf:

- soil 6 to 8 inches deep that allows good root growth by supplying adequate water and nutrients
- soil pH approximately 6.2
- adequate moisture
- temperatures appropriate to the species selected
- adequate nutrients
- appropriate level of sunlight
- properly adjusted and sharp mower
- adequate air movement

VCE publications 424-100
Selecting Turfgrass pamphlet

VIII. Nutrient Management:

Nutrient management is an integral part of any golf course maintenance plan. Many factors can be taken into account when formulating a plan for applying nutrients to golf course turf grass including, but not limited to:

- soil type and CEC of the soil
- rainfall
- evapotranspiration and temperature in the given location
- leaching indices
- proximity to water

By taking these factors into account the potential of the nutrient to run off or leach below the root zone of the turfgrass can be decreased. When either of these actions occur, the nutrient may contaminate surface and/or ground waters. If the golf course lies near a stream or river, the consequences of these actions can be severe. Additionally, applying nutrients that will not be used by the grass is a waste of time and money. Through awareness of the conditions on the course, specifically of the factors listed above, fewer nutrients will be wasted and the potential for environment detriment will be reduced.

Environmental Risk Assessment:

As stated in "Nutrient Management Handbook" (DCR), some fields are more likely to contribute nutrients to ground and surface water than are others. Some environmentally sensitive site features require intense nutrient management practices. High-risk areas include:

- high leaching index soils
- land with sinkhole drainage
- shallow soils over fractured bedrock
- irrigated land
- land prone to surface loss of nutrients due to slope
- highly erodible soils
- land in close proximity to surface water

▶ How to assess environmental risks:

Locate the leaching indices that apply to the soils at a specific course in the Soil List section of this manual. Also factor in the location of the course in proximity to water, the temperature, and the annual rainfall. For example: if the majority of the leaching indices that apply to your course are "moderate", wise nutrient management should be practiced (as stated on page 17). If the same course also borders a stream, has steeply sloped fairways, shallow soils, or if heavy rainfall is imminent, nutrient management should be intense or soluble nutrients should not be applied until conditions are more favorable.

**loosely translated from conversation with David Kindig, DCR

Fertilizer Recommendations:

Rate, timing, and technique of fertilizer application are factors that determine a sound nutrient management plan. Supplying the grass with optimal levels of nutrients while reducing the potential for leaching and runoff is the ultimate goal in nutrient management.

Certain practices will help reduce the amount of fertilizers and nutrients entering the surrounding waterways:

- Use a drop spreader near bodies of water or imperviouse surfaces such as walkways or parking lots. Spinner spreaders or broad cast spreaders should not be used near bodies of water because of the potential of granules entering the water.
- Minimize fertilizer rates on slopes. The application of high rates of nitrogen and phosphorus fertilizer on slopes near surface water increases the risk for negatively impacting water quality. Use not more than 0.25 to 0.50 pounds of nitrogen per 1000 square feet per application.
- Do not apply fertilizers directly into lakes, drainage areas, and other bodies of water.
- Maintain a buffer zone of low-maintenance grasses or natural vegetation between areas of highly maintained turf and water. This prevents erosion and produces a trap or filter for unwanted runoff of nutrients.

Several specific nutrients are needed in higher concentrations to assure optimal plant growth. The following nutrients will be discussed in this manual:

- nitrogen
- phosphorus
- potassium
- lime and sulfur as pH determinants
- iron.

Nitrogen:Phosphorus:Potassium ratios in various forms and concentrations are commonly found in turf fertilizers. Lime and sulfur have direct effects on soil pH and also increase or decrease the effectiveness of various other nutrients. A basic understanding of each nutrient and recommendations for application rates and times is essential to proper turf management.

While there is minimal concern for *lime, sulfur,* or *iron* moving into surface or ground water supplies, these nutrients are addressed in a soil test and are key factors in turf health.

**Water Quality and GC Supers, NCCES
Nutrient Management Handbook, DCR

IX. Nutrient Recommendations:

Nitrogen (N)

Nitrogen is the nutrient needed in highest amounts for turfgrass growth and development. Nitrogen comes in two basic forms: readily or quickly available and slowly available.

Readily Available N

Nitrogen is water soluble, immediately available for plant uptake. This type of N is used up by the plant after 3-6 weeks. It results in short periods of plant response. Readily available N is most susceptible to leaching below the root zone. Predominately quickly available N sources contain less than 50% water insoluble nitrogen (WIN).

Slowly Available N

These sources are predominately more than 50% water insoluble nitrogen (WIN) or contain soluble N coated in protective coatings or sealants in which microbial or physical action is required to release the nitrogen. N can last in the soil for 8-12 weeks or more and is applied less frequently and at sometimes higher rates than readily available forms. Slowly available forms are less susceptible to leaching and are preferred in environmentally sensitive sites. The percent that is water insoluble should be listed on the label of the fertilizer. Whatever is not WIN should be considered readily available N. To determine the amount of WIN in fertilizers refer to this equation:

$$\frac{\%\ \text{WIN}}{\%\ \text{Total N}} \times 100 = \%\ \text{of total nitrogen that is WIN (slowly available)}$$

Example:

Fertilizer ingredients read $N:P_2O_5:K_2O$ = 16:4:8

Total Nitrogen…………………16%

5.6 % WIN

Available Phosphoric Acid……4%

Soluble Potash…………………8%

Therefore:

$$\frac{5.6}{16} \times 100 = 35\%\ \text{of the total nitrogen is slowly available (WIN)}$$

This fertilizer would be considered a source of readily available nitrogen because WIN is less than 50%.

Figure 3

NITROGEN SOURCES in Turf Fertilizers

SOURCE	COMMON ABBREV	AVG % NITROGEN	RELEASE MECHANISM; AVAILABILITY
Ammonium Nitrate	NH_4NO_3 (AN)	31-35	Water soluble, fast
Ammonium Sulfate	$(NH_3)NO_3$	21	Water soluble; fast
Urea	$CO(NH_2)$	45-46	Water soluble; fast
Calcium Nitrate	Ca(NO3)2	15-16	Water soluble; fast
Urea Formaldehyde	UF	38	Microbial* activity; temp, pH, moisture dependant; slow
Sulfur-coated Urea	SCU	10-38	Microbial breakdown of S coating; particle size, temp, coating thickness dependant; slow
Isobutylidene diurea	IBDU	31-32	Hydrolysis to urea; particle size, pH, moisture dependant; slow
Resin coated Urea	RCU	20-41	Osmosis of water into pellet; coating thickness and moisture dependant; slow
Milorganite	Biosolids, organic complex	6	Microbial activity; temp, pH, moisture dependant; slow

---from "Nitrogenous Fertilizers in Turfgrass Systems; Impact on Water Quality" -- VaTech, 1997

- *Soil moisture, temperature, and pH determine Rate of microbial activity. Slow release sources that depend on microbial action for breakdown to available N may give poor to moderate response in cold weather.
- Slow release nitrogen sources reduce the number of applications necessary, minimize labor costs, and reduce the risk of foliar burn and leaching.
- Split applications of readily available sources of nitrogen reduces the leaching potential.
- Use slowly available N on sandy soils; it has a lower leaching potential on highly leachable soils.
- If using quickly available N on sandy soils or near shallow water tables, use no more than 0.25 to 0.5 pounds per 1000 square feet per application. Plant response is often better under lower levels of nitrogen with more frequent applications.
- Do not apply quickly available N before a heavy rain or irrigation event or during cool temperatures as the leaching potential increases under these conditions.
- Irrigate in amounts of 0.25 to 0.5 inches after applications of quick release N. Water will move the fertilizer into the ground, will decrease loss by runoff and volatilization, and will decrease the risk of foliar burn.

**Nitrogenou Fertilizers. VaTech, 1997
Water Quality and GC Supers, NCCES

Nitrogen Application

Proper timing on nitrogen applications differ with cool and warm season grasses.

Cool Season Grasses

Nitrogen fertilization of cool season grasses in the summer and spring is environmentally unsound because the root system at this time of year is relatively small and unable to efficiently absorb applied nitrogen. Late fall and winter is when cool season grasses begin to develop their root systems. Excessive nitrogen fertilization of cool season grasses in the spring promotes leaf growth at the expense of root growth, whereas an extensive root system is needed to absorb the nitrogen applied in the late summer and fall.**

■ *The best time to fertilize cool season turf grasses is from August 15 through November.*

Programs 1 and 2 from Virginia Tech and Virginia Cooperative Extension apply to cool season grass fertilization.

Figures 4 & 5
Fertilization Programs for Kentucky Bluegrass, Tall Fescue, Perennial Ryegrass, and Fescue Turf:

Program I. Using predominantly quickly available nitrogen fertilizers (less than 50% slowly available nitrogen or WIN)

Nitrogen Application by Month

Quality Desired	Sep	Oct	Nov	May 15-Jun 15
	-----lbs N / 1000 Sq Ft -----			
Low	0	1	0	0-1/2
Medium	1	1	0	0-1/2
High	1	1	1	0-1/2

Program II. Using predominantly quickly available fertilizers (50% or more slowly available nitrogen or WIN)

Nitrogen Application by Month

Quality Desired	Aug 15 to Sep 15	Oct 1 to Nov 1	May 15 to Jun 15
	-----lbs N / 1000 Sq Ft -----		
Low	1.5	0	0
Medium	1.5	1.5	0
High	1.5 to 2	1.5 to 2	0to 1.5

**Important comments about Programs 1 and 2:

- Fine fescues perform best at lower levels of nitrogen.
- Applications in successive months should be approximately 4 weeks apart.
- Natural organic and activated sewage sludge products should be applied early in the Aug. 15 to Sept. 15 and the Oct. 1 to Nov. 1 application periods to maximize their effect.
- Up to 1 pound of N in Program 1 and up to 1.5 pounds of N in Program 2 may be applied per 1000 square feet in the May 15 to June 15 period if N was not applied the previous fall or to help a new lawn get better established.

Warm Season Grasses

Fertilization of warm season grasses in the late fall and winter is not recommended as their root systems are relatively inactive at his time. These grasses take up the greatest amount of nitrogen after spring green-up and throughout the summer. They are capable of efficiently and effectively utilizing spring and summer applied nitrogen from late April through mid-September in most areas of Virginia.**

- *The best time to fertilize warm season grasses in between April 1 and August 15.*

Programs 3 and 4 from Virginia Tech and Virginia Cooperative Extension apply to warm season grass fertilization.

Figures 6 & 7
Fertilization Programs for Bermudagrass, Zoysiagrass, and Centipedegrass Turf:

Program III. Using predominantly quickly available nitrogen fertilizers (less than 50% slowly available nitrogen or WIN)

Nitrogen Application by Month

Quality Desired	Apr	May	Jun	Jul/Aug
	-----lbs N / 1000 Sq Ft -----			
Low	0	1	0	0
Medium	0	1	10	0
High	1	1	1	1

Program IV. Using slowly available nitrogen fertilizers (50% or more slowly available nitrogen or WIN)

Nitrogen Application by Month

Quality Desired	Apr/May	Jun/Jul	
	-----lbs N / 1000 Sq Ft -----		
Low	2.0	0	
Medium	1.5	1.5	0
High	2.0	2.0	

Important comments about Programs 3 and 4:

- If overseeded for winter color add 0.5 to 1 pound of readily available N per 1000 square feet in September/October and/or November.
- Applications in successive months should be approximately 4 weeks apart.
- Centipedegrass and mature zoysiagrass perform best at 1 to 2 pounds of N per 1000 square feet per year.

**VCE publication 430-398

Phosphorus (P)

The second primary nutrient needed by turfgrass is phosphorus. Plants require phosphorus in much smaller quantities than nitrogen. Phosphorous is very immobile in soils. Turfgrass is efficient at extracting phosphorous from the soil if the turf is well established. Excessive phosphorus in the soil can interfere with iron and zinc uptake by turfgrass roots. Availability of phosphorus is dependent on the pH of soil.

Surface soil layers contain higher levels of phosphorus and may be eroded. To keep phosphorus from entering surface waters and causing environmental damage, soil tests should be performed to determine the amount of the nutrient in the soil.

If a soil tests high for phosphorus:

- suspend use of broadcast fertilizers containing phosphorus
- avoid routine phosphorus applications

If a soil test indicates a phosphorus deficiency:

- do not apply more than 2 pounds P_2O_5 per 1000 square feet to established turf at any one time
- incorporate phosphorus 1-2 inches into the soil for newly planted turf

In absence of soil test:

- apply phosphorus no more than once per year
- use fertilizers containing a nitrogen to phosphorous ratio of at least 3:1

Figure 8

Phosphorus Fertilizer Recommendations for Turfgrass Based on Soil Test Results

Soil Test Available P --ppm--		lbs. P_2O_5 / 1000 sq ft / year	
	General Turf	High Quality Turf	New Turf
0-5 (very low)	3	4	5
6-10 (low)	2	3	4
10-20 (medium)	1	2	3
20-50 (high)	0	0-1	1-2
50+ (very high)	0	0	0

**Water Quality and GC Supers, NCCES
Nutrient Management Handbook, DCR

Potassium (K^+)

Potassium is another nutrient necessary for turfgrass growth and health. Potassium plays an important role in enhancing tolerance against extreme temperatures, disease, and wear and tear.

Potassium does not move readily in dry soils but can show significant movement in wet soils or sandy soils. Techniques that can reduce the loss of potassium from soils include:

- increasing the amount of organic matter in the soil (use of plant residue fertilizers)
- in sandy areas; apply in smaller quantities and more often to improve plant uptake and reduce leaching potential

▸ Potassium is typically not a concern to water quality. Rates should be applied according to soil test results.

Potassium content in fertilizers is usually expressed as % potash (K_2O) even if the actual form in the fertilizer is another available form of K^+. Available potassium comes in various forms:

Name	Chemical Formula	% K_2O
Potassium Chloride	KCl	60
Potassium Sulfate	K_2SO_4	50
Potassium-Magnesium Sulfate	K_2SO_4*2$MgSO_4$	22
Potassium Nitrate	KNO_3	44
Manures	varying	1-2

- Soil tests will report the amount of potassium in the soil that is available to the turfgrass.
- If soil test indicates a very low to medium concentration, refer to the following chart:

Figure 9

Potassium Fertilizer Recommendations for Turfgrass Based on Soil Test Results

Soil Test Available K^+ --ppm--		lbs. K_2O / 1000 sq ft / year General Turf	High Quality Turf
0-40	(very low)	4	5
41-175	(low)	2-3	3-4
175-250	(medium)	0-1	2
250-300	(high)	0	0-1
300+	(very high)	0	0

▸ do not apply more than 1.5 lbs of K_2O / 1000 sq ft. to established turf at any one time

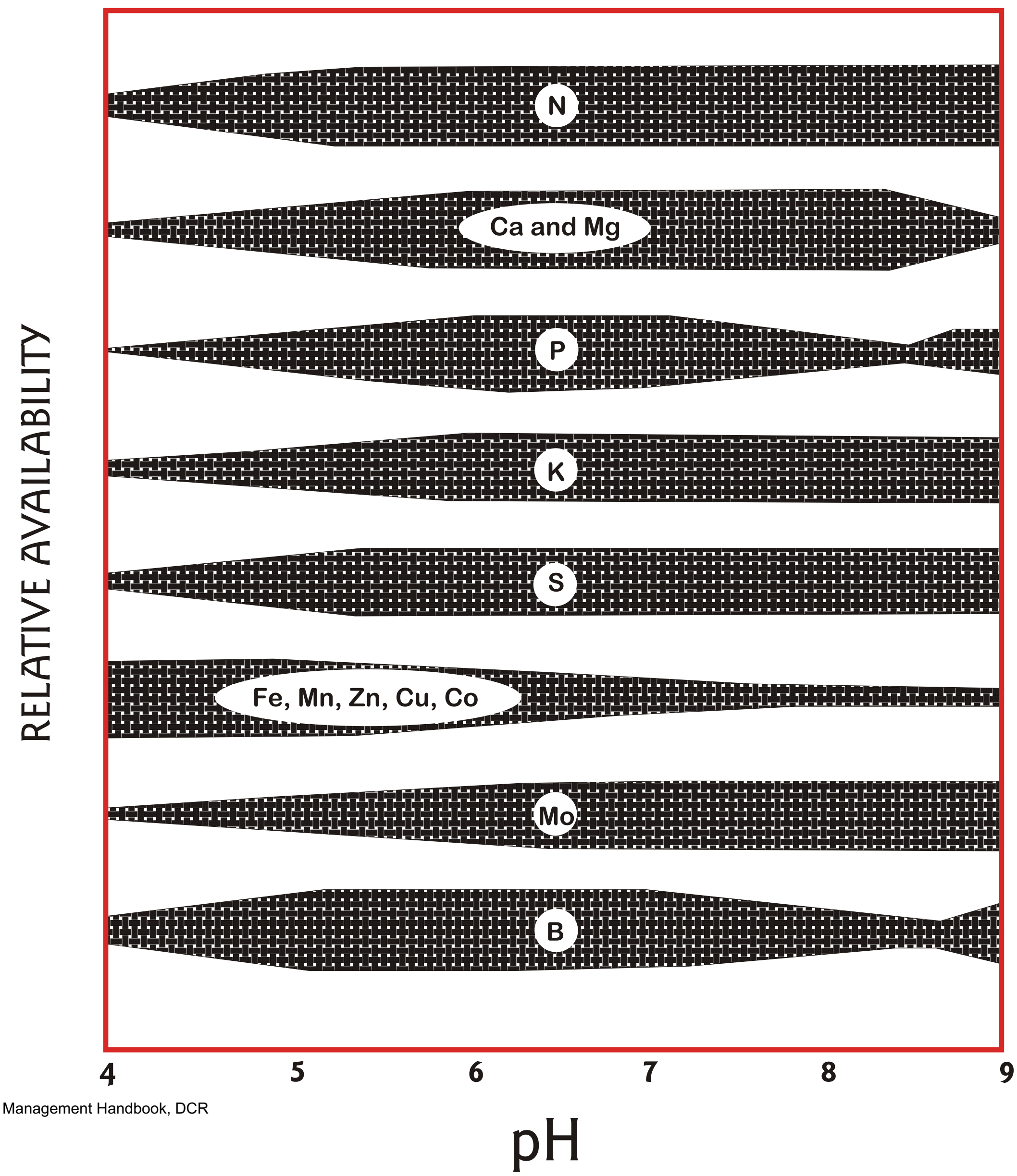
**Water Quality and GC Supers, NCCES, Nutrient Managemnt Handbook, DCR

Soil pH

Soil pH is a measure of the acidity or alkalinity of the soil. A pH of 7.0 is neutral; acidic soils have a pH below 7.0 and basic soils have a pH above 7.0. Nutrient availability in the soil is directly related to soil pH. Nutrient uptake is optimal at a pH between 6.0 and 7.0. At low pH, below 5.0 specifically, some metals within the soil become available at toxic levels. As pH rises from 5.0 to 8.0, several essential elements tend to become less available.

Figure 14 illustrates the relationship between soil pH and the plant availability of nutrients.

Figure 10
Effect of pH on Nutrient Availabilities for Plant Uptake



**Nutrint Management Handbook, DCR

Soil pH, cont.

Lime is used to increase the pH of acidic soils whereas *sulfur* is used to decrease the pH of basic soils. Either material should be incorporated into the soil before planting if needed. When applying some types of lime and sulfur to established lawns, turf cover prevents the materials from being properly incorporated and there is a risk of burning the turf, especially if the air temperature is above 80 degrees F. With established lawns, lime and/or sulfur may have to be incorporated into the soil in smaller quantities at repeated doses to avoid burning the turf.

Soil testing for a desired pH adjustment considers several factors:

- soil texture
- active acidity (H^+) and reserve acidity (Al^{3+}).

Aluminum in the soil acts as a buffer against changes in pH. Soils with a high clay or silt concentration resist pH changes due to higher aluminum content.

- fine textured soils will require more lime or sulfur to adjust the pH
- coarse, sandy soils have a lower buffering capacity and require less lime or sulfur to adjust the pH of the soil

The composition and buffering capacity of the soil will be determined in the lab and proper amounts of lime or sulfur will be indicated to adjust the pH to the desired level.

Adjusting soil pH can be a slow process on turf lawns. Because of the difficulties associated with changing the soil pH under established turfgrass, no adjustments are recommended if the pH is between 6.2 and 7.0.

- If grass is actively growing, this is an indication that the pH does not need adjusting.

- *Never apply lime or sulfur unless a soil test indicates that one or the other is actually needed.*

**Nutrint Management Handbook, DCR
Water Quality and GC Supers. NCCES

Lime

Lime is a natural mineral consisting of calcium, magnesium, and carbonates. Lime comes in various forms, each with a varying concentration of calcium carbonate ($CaCO_3$). Pure $CaCO_3$ has an acid neutralizing value (NV) or Effective Calcium Carbonate (ECC) concentration of 100%. This number is assigned to $CaCO_3$ in order to compare other forms of lime and their abilities to neutralize soil acidity.
NV or ECC greater than 100% means only that the substance has more capability to neutralize soil acidity than pure $CaCO_3$.

Acid neutralizing values for specific lime materials:

Lime material	Chemical composition	NV or ECC (%)
Calcium carbonate	$CaCO_3$	100
Calcitic limestone	$CaCO_3$	85-100
Dolomitic limestone	$CaMg(CO_3)_2$	95-108
Calcium hydroxide (hydrated limestone)	$Ca(OH)_2$	150-175
Calcium oxide (burnt/quick limestone)	CaO	110-135
Marl (selma chalk)	$CaCO_3$	70-90
Calcium silicate	$CaSiO_3$	86
Slags	$CaSiO_3$	50-70
Ground/burned oyster shells	$CaCO_3$`	90-110
Cement kiln dusts	varying	40-100
Wood ashes	varying	40-50
Power plant ashes	varying	25-50

**Nutrient management Handbook, DCR
Aglime Facts

Particle size of the lime material plays a role in the ability to neutralize soil acidity. Finer ground particles are more readily available for acid neutralization. Larger particles may take longer to be incorporated completely within the soil and take longer to raise the pH of the soil. *Pelletized lime* is the granulated form of calicitic or dolomitic lime.

Soil tests will indicate the amount of lime needed to adjust soil pH to an optimal level. The soil test assumes that the material used to raise the pH will have an ECC value of 100%. If a material with a different ECC value will be used, the amount applied may need to be adjusted. If the material used to raise the pH is slag, with a NV of 50%, the amount applied should be doubled to get the desired effect indicated under the "lime requirement" on the soil test results.

Soil tests indicate the amount of lime needed to raise the pH of a soil under a newly established lawn or green where the material can be mixed into the soil to an effective depth of six inches. When applying lime to the soil it is important to incorporate the lime thoroughly into the soil to ensure that the material can effectively neutralize acidity. Calicitic or dolomitic lime sources are typically applied to established turf. To avoid the risk of burning turf, avoid Ca(OH)2 and CaO on established stands.

Lime, cont.

Benefits of liming:

- reduction in activity and solubility of aluminum (Al) and manganese (Mn) - toxic metals
- application of calcium (Ca) and magnesium (Mg) - essential nutrients that have low concentrations in acidic soils
- increased phosphorus (P) availability
- increased availability of other essential micronutrients
- improved soil structure
- improved efficiency of some herbicides

Over liming, however, can raise the pH to levels where micronutrients become deficient.

Note:

- Do not apply more than 50 pounds per 1000 square feet at one time
- Do not apply more than 25 pounds per 1000 square feet at one time on close cut turf
- If using calcium oxide (CaO) or calcium hydroxide ($CaOH_2$) do not apply more than 25 pounds per 1000 square feet at one time

**Nutrient management Handbook, DCR
Aglime Facys
Water Quality and GC Supers. NCCES

Sulfur

Sulfur in the soil is generally in the form of sulfate (SO_4^{2-}). Sulfate is not the source of acidity in soils; some forms of sulfate are acidic and will decrease soil pH while others are neutral salts and do nothing to effect soil pH.

<u>Sulfates that do not effect soil pH (neutral salts):</u>

gypsum	$CaSO_4$
potassium sulfate	K_2SO_4
magnesium sulfate	$MgSO_4$
potassium magnesium sulfate	K-Mag

<u>Sulfates that contribute greatly to soil acidity (acidic compounds):</u>

ammonium sulfate	$(NH_4)_2SO_4$
iron sulfate	$FeSO_4$

Ammonium sulfate and iron sulfate can be incorporated into the soil to reduce the pH of alkaline soils. Alkaline soils reduce the availability of some micronutrients and can increase the risk of iron chlorosis, or a yellowing of the turf.

As with lime, ammonium sulfate and iron sulfate must be incorporated into the soil for maximum efficiency in lowering soil pH. For new lawns, incorporate S into the soil to a depth of 6 inches before planting at the following rates. For established turf, halve the rate and apply only during the fall or spring in conjunction with core cultivation.

- Do not apply more than 5 pounds elemental S per 1000 square feet at one time
- If applying elemental S to bentgrass putting greens, do not apply more than 2 pounds per 1000 square feet at one time
- If applying elemental S to annual bluegrass putting greens, do not apply more than 0.8 pounds per square feet at one time
- Iron sulfate should only be used if a turf green-up is desired as well a decrease in soil pH

Commercial fertilizers previously contained significant amounts of sulfates. Recently, however, use of high analysis fertilizers such as urea contain little or no sulfates has caused much less application of this essential nutrient.

▶ The sulfate ion is not strongly held in the soil and can readily be leached from most soils

▶ Avoid the use of elemental sulfur

**Nutrient Management Handbook, DCR
Water Quality and GC Supers. NCCES
KSU Hort Report

Iron (Fe)

Iron is a micronutrient that has various beneficial effects on turfgrass. Iron is required for the synthesis of chlorophyll and a deficiency will lead to chlorosis. Iron applications to turfgrass have shown to increase chlorophyll content, carbohydrates and rooting while decreasing respiration rates. Iron is often deficient in turf especially in alkaline soils. Any condition that restricts or inhibits turfgrass rooting can also cause an iron deficiency including :

- excessive watering
- compaction
- excessive nitrogen levels
- disease or insect injury

Iron chlorosis occurs in a random, patchy pattern of yellowing while nitrogen deficiencies occur in a more uniform manner. Iron is not mobile within the turf and deficiency symptoms are exhibited on the new leaves.

Iron sulfate ($FeSO_4$) can be applied to turf with the effect of green-up within 24 - 48 hours. Iron sulfate can be used as an alternative to nitrogen or in combination with nitrogen for green-up purposes. Reduced nitrogen applications will minimize possible nitrate leaching and runoff.

Iron sulfate will also reduce the pH of the soil so should only be applied to alkaline soils.

Iron sulfate ($FeSO_4$) and Iron chelates can be applied to turf to achieve green-up.

- Use $FeSO_4$ at a rate of 0.25 pounds per 1000 square feet.
- this application may only last a few weeks
- apply in late spring through summer for cool season grasses
- apply in the fall for warm season grasses
- Use Iron chelates at a rate of 0.1 pounds per 1000 square feet.
- may have a longer lasting effect on the turf
- may cost more than $FeSO_4$
- if the soil pH is above 7.2 use only Fe-EDDHA.

Soil tests may not properly indicate the need for iron. An effective diagnosis is to spray a small test area with iron sulfate and observe the area for 24-48 hours to see if a response occurs. Because iron is commonly deficient in alkaline soils, the only long-term solution is to acidify the soil.

To allow for maximum uptake of iron by the turfgrass:

- do not apply iron if rain is imminent
- do not irrigate for at least 3 - 4 hours after the application

**Nutrient Management Handbook, DCR
Water Quality and GC Supers. NCCES
Standards and Criteria, DCR

X. Mowing/Grasscycling:

Mowing height plays a direct role in the success of turfgrasses. Mowing is a stress-creating management practice. Each species of turfgrass has a mowing height range throughout which it can be expected to provide a satisfactory turf in various climatic conditions. If the turf is mowed too short or too frequently, the leaf density increases while root and rhizome growth decreases. Mowing too short increases the need for more frequent mowing and makes the turf less tolerant of environmental stresses, more disease prone, and more dependent on water, nutrient, and pesticide inputs. This increased maintenance not only leads to higher costs, but also to an increased risk of runoff. The best approach is to use the highest mowing height acceptable for the use being made of the turf and to never remove more than 33% of the existing foliage at one time.

Time, pattern, and type of mowing can also influence turf quality. Avoid mowing grasses under extremely wet conditions to avoid clumping and spread of disease. Also avoid mowing during extreme heat, which increases the need for water and chemical inputs.

- Grasscycling, or returning clippings to the turf surface in non-play areas, is a very efficient way of recycling nutrients.
- Every 100 pounds of dried grass contains approximately 4 pounds of nitrogen, 0.5 pounds of phosphorus, and 2 pounds of potassium.
- These reusable nutrients may reduce fertilizer requirements and costs by up to 25%.
-

Clippings decompose rapidly and, despite controversy, have not shown to cause a significant build up in thatch.

Clippings can also be combined with leaves and composted. Finished compost can be used as a soil modifier or mulch.

▸ Because of the high amounts of nutrients in clipping, collected clippings should not be placed in areas where they have a high probability of blowing away or running off into surface waters.

**Water Quality and GC Supers
VCE pubs. 430-398, 430-399

XI. Irrigation:

Because of increased water input, irrigated lands are susceptible to runoff and leaching of water and nutrients. To maximize water use efficiency and to decrease the cost of irrigation, proper irrigation methods and scheduling should be incorporated into a golf course management plan.

Determining the appropriate level of irrigation for an area of turfgrass is vital to the health of the plant and the preservation of water quality. Under irrigating produces wilt and desiccation. Over-irrigating increases the potential for leaching and surface runoff and weakens the turf, making it more prone to pest attacks and environmental attacks.

A properly designed and installed irrigation system will apply a uniform level of water at the desired rate and time. The amount and frequency of irrigation should be based on

- the needs of the grass
- soil conditions
- expected weather conditions

The goal is to wet the soil to a depth just below the root zone to encourage further rooting. Watering deeper than the root zone does not benefit the plant, may leach contaminants to groundwater, and is costly.

To obtain the most benefit from irrigation practices:

- water to a depth just below the root system
- if runoff occurs, stop irrigation until water enters soil; rewet until water reaches appropriate depth
- irrigate in short, frequent intervals on sloped areas, sandy soils, and compacted soils
- water early in the morning
- if watering in the evening, allow for leaves to dry before nightfall to lessen the chance of disease
- avoid mid-afternoon watering to reduce loss to evaporation
- do not plan to water turf before it is used by heavy traffic - wet, compacted soils lead to runoff
- do not plan to water before a significant rainfall event
- periodically test the irrigation system to make sure it is producing an acceptable level of uniformity
- keep velocities low to manage runoff
-

**Water Quality and GC Supers, NCCES

XII. Aeration:

Heavy traffic on golf course turf can lead to compaction and an increase in runoff, nutrient demand, and cost. Core aerification improves numerous aspects of the turf system including, but not limited to:

- air exchange
- water infiltration rates
- water retention
- nutrient penetration
- root development
- thatch decomposition

Aerification can be used along with proper irrigation techniques to increase water efficiency and thereby reduce total irrigation requirements. Coring sloped areas can also reduce runoff.

On heavily trafficked cool-season grasses:

- aerify during periods of active foliar growth during the fall or spring
- mid-summer aerification can be beneficial if irrigation is available and temperatures are favorable

On heavily trafficked warm-season grasses:

- aerify from green-up in the spring to dormancy in late August approximately June 1 August 15th. This is when the grass is actively growing and can recover from injury associated with aerification.

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XIII. References

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